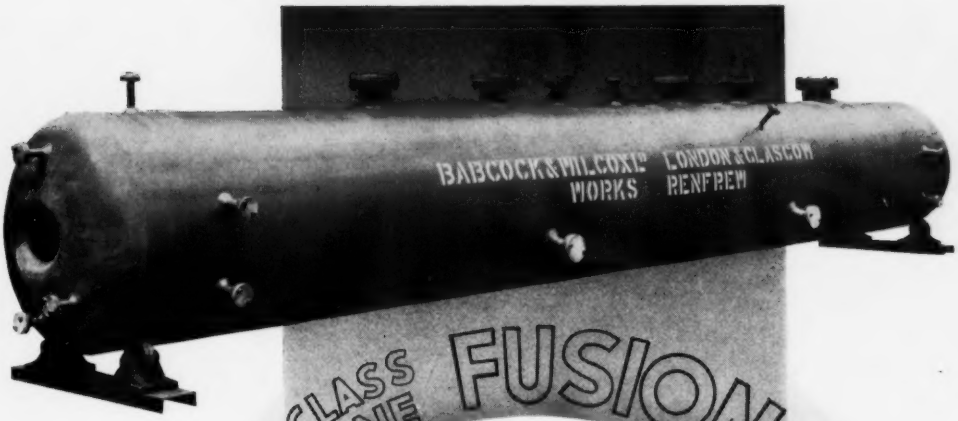

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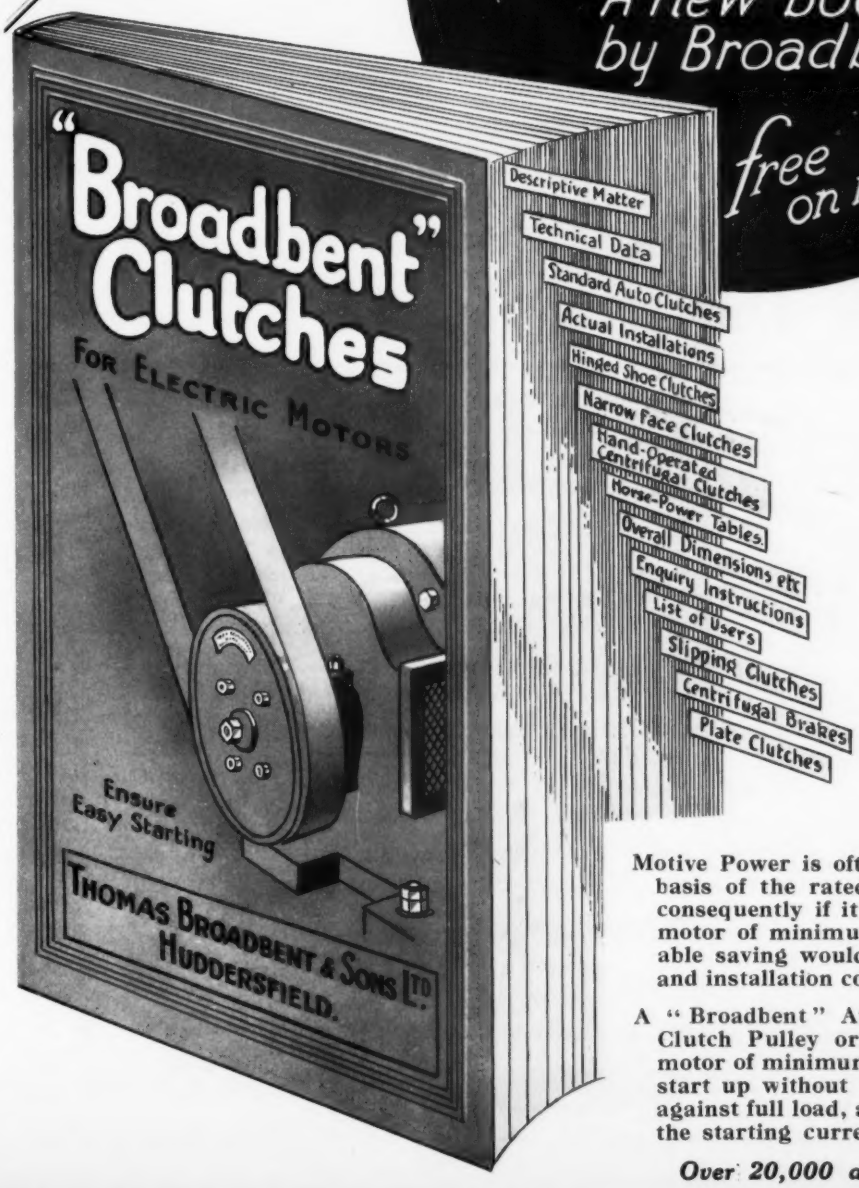

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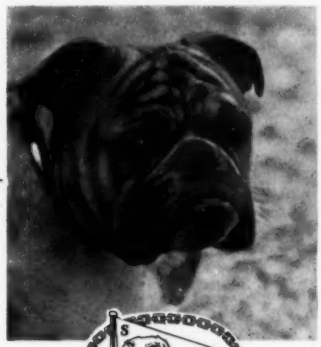

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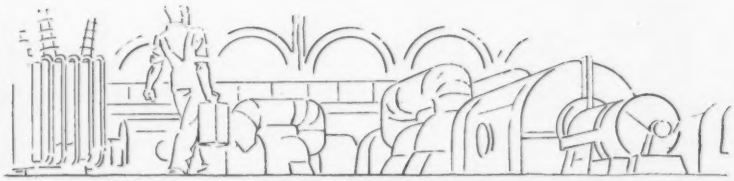

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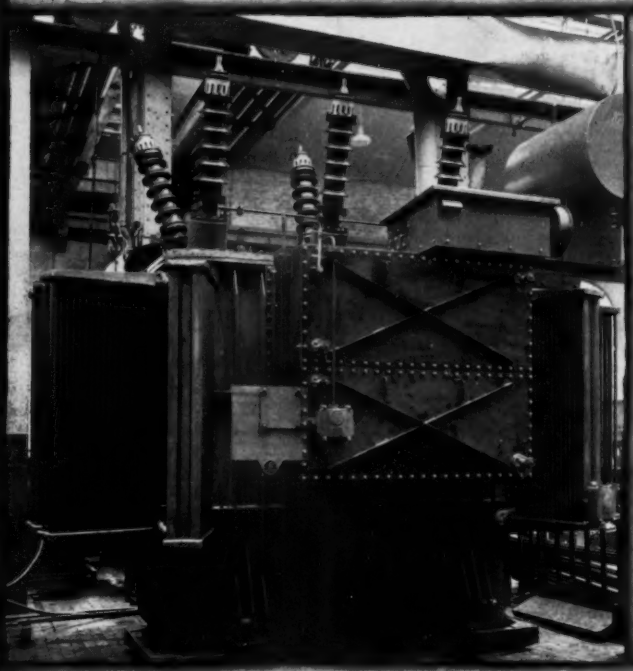

66 kV Oil-Filled Condenser Type Outdoor Bushing for Transformer Service.

The illustration shows the H.V. side of an Outdoor Transformer fitted with Remote Controlled On-Load Tap Changer. It has a rating of 7,500 KVA 3-phase 50-cycles, 60,000—30,000 33,000 volts connected Star Star. This Transformer is fitted with our 66 kV Outdoor Condenser Type Oil-Filled Bushings and was manufactured by The English Electric Co., Ltd., Stafford, to whom we are indebted for permission to use this illustration

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The ENGLISH ELECTRIC JOURNAL

Queen's House from Lincoln's Inn Fields.

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Vehicles exhibited at the International Commercial Motor Transport Exhibition, Olympia, 1935.

The upper illustration shows a double deck 48-seater bus of composite reinforced construction, on a Leyland Titan chassis, and the lower illustration an "A.E.C.-English Electric" 50-seater double deck trolley bus of all-metal welded construction.

The English Electric Journal

Vol. VII. No. 7 NOVEMBER, 1935 One Shilling.

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

Our frontispiece illustrates two of the three exhibits shown on the Company's Stand at the recent International Commercial Motor Transport Exhibition, Olympia. The upper illustration shows a double deck bus body as supplied to Blackpool Corporation, it will be noted that the lines of the body follow that of the double deck streamline luxury tramcars recently supplied by the Company to the same Corporation.

The lower illustration shows an A.E.C.-English Electric trolley bus supplied to Portsmouth Corporation, the Company have recently received an order for the supply of 76 trolley bus equipments on A.E.C. chassis for this Corporation.

The first article in this issue is devoted toadescription of Neon Sign transformers. Neon advertisement signs are now a familiar feature in practically every town and city, in this country; the highly penetrative properties of the Neon light make it eminently suitable for use on signs which have to be read from a long distance. In this article Mr. T. A. Long discusses the various problems associated with the design of these transformers, and describes the design adopted by the Company to overcome them.

The second article describes and illustrates the new additions to the Company's range of Domestic, Heating and Cooking Appliances. The "A" series of Cookers have been developed in

order to assist Supply Undertakings in meeting competition from other forms of cooking. The new coal-effect fire incorporates a very realistic flicker device producing the effect of rising flames and smoke. Inset fires and wall-type fires are dealt with, and the new designs should be of assistance to architects and builders in the construction of modern houses.

The new 1½ gallon "push" type Water Heater (Cat. No. HW. 1001) has been designed to overcome to a large extent the trouble due to furring; it should therefore have a particular appeal to electricity supply undertakings and contractors located in "hard water" districts. Mr. Gillott's article also describes the new washing machine recently put on the market by the Company after exhaustive tests, the streamline electric iron and handidrier, the latter being very useful for the safe drying of light articles such as stockings and gloves.

The final article is devoted to a reprint of a Paper by Mr. J. E. Calverley, entitled "The Electrical Equipment of Trolley Vehicle Routes," which was read before the Tramways and Light Railways Association at Llandudno. In the unavoidable absence of Mr. Calverley, the Paper was presented by Mr. L. H. Short and our reprint is preceded by his introductory remarks.

The Paper gives the benefits to be derived from the use of regenerative control, and refers to the fact that due to the progress in rectifier design and the increasing availability of power supplies in outlying districts, there has been a tendency to increase the number of sub-stations. The Paper also reviews the protection of converting units, suppression of interference with wireless reception and current collection.

This article will be concluded in the next issue of this Journal.

TRANSPORTATION OF 73-TON MILL MOTOR ARMATURE.

The illustration shows the armature of the 20,000 H.P. (peak) Reversing Mill Equipment which the Company are supplying to Messrs. British (Guest, Keen Baldwins) Iron and Steel Company, Ltd., Cardiff, mounted on the special 14-wheeler articulated Lorry required for its transport to Cardiff. The armature and coupling as despatched weighed approximately 73 tons, and a week was required for the journey to Cardiff.

Neon Sign Transformers.

By T. A. LONG, A.M.I.E.E.

During the last few years outstanding advance has been made in the field of illumination, especially in decorative and display lighting.

The advent of the luminous discharge tube, with its wide flexibility of colours and the ease with which it is possible to bend the tube to practically any desired shape, has contributed largely to this progress. In addition, this form of lighting has a light efficiency in lumens per watt many times that of the incandescent lamp. It is thus possible to employ economically luminous tubes for display lighting under conditions where the cost of any other form of lighting would prove prohibitive.

The general application of luminous discharge tubes for lighting has been covered, somewhat inaccurately, by the term "Neon Lighting." Strictly, the term "Neon Light" can only be applied to the luminous tube which is filled with neon gas, and which, when under voltage stress, is illuminated by the well-known characteristic red light. However, by filling the luminous tube with other inert gases such as argon, helium or certain combinations of gases, it is possible to obtain a wide variety of colours and the fantastic effects of quickly moving light often seen in advertising displays.

Advantages and Applications.

One well-known neon sign manufacturer has recently introduced an interesting and novel scheme having wide possibilities of application. The scheme (which is protected by letters patent) consists of supplying an attractive display stand into which may be plugged luminous tube letters. In this way any desired word of advertising value, or even a complete message, may be vividly brought to the attention of the public. At the same time a complete library of letters is available at numerous centres, so that for a very nominal charge the letters may be changed to allow a new word or message to be conveyed. This scheme should prove especially valuable to cinemas or theatres with their frequent change of programme.

A higher degree of definition can be obtained with the luminous tube than with incandescent lighting. It is therefore eminently suitable for advertisement signs which require to be read from long distances.

The highly penetrative properties of the neon light make it suitable for use as aerodrome beacons. An interesting example of this type of application is the aerodrome beacon at Croydon, which takes the form of neon tubes arranged in a truncated cone formation. It is arranged to flash a morse signal indicative of the aerodrome, and it is claimed that the average range of visibility is fifty miles. The light from a neon tube is of low intrinsic value but of large area, the advantage gained being the complete absence of glare, which might be discomforting to the descending pilot. In addition, at Croydon aerodrome, neon tubing is used to mark out landing strips. The neon tubing is fixed below ground level and covered by strong glass covers. This system has proved to be remarkably successful, and it is claimed that it is the only one of its kind in the world.

The use of luminous tubes for the interior lighting of the ordinary household opens up a very wide vista of possible application. It is believed by a number of reputable neon sign manufacturers that it is in this direction that the next notable developments will advance, and considerable time and thought is being spent on this particular application. At the present time, however, the luminous tube is far behind the filament lamp from the point of view of electrical simplicity. It is, of course, not easily possible to predict the advances which will be made in the future. It must be remembered, however, that, although the commercial application of luminous tube lighting is comparatively recent in

this country, it has been used very extensively in the United States and on the Continent without any notable advance towards simplification.

The luminous tube most widely used for lighting is the cold cathode tube. Except for very short lengths the cold cathode tube requires a high voltage to start the luminous discharge, and this necessitates the use of a high voltage transformer.

It is well known that the phenomena of current conduction through a gaseous path, such as is the case in luminous discharge tubes, does not follow Ohm's Law. A higher voltage is required to initiate the discharge than is required to maintain it. It is on account of this so-called negative impedance characteristic that some form of current-limiting device is required to be incorporated in the circuit. For the same reason the terms "Striking voltage" and "Running voltage" become evident. The ratio of striking to running voltage varies with the length of the column of gas, the pressure and nature of the gas, and also to some extent upon the shape and composition of the electrodes. As a guide, the ratio of striking to running voltage is approximately 2.0/1 to 1.7/1. The voltage drop across a length of luminous tube is usually divided into two components :—

(1) The electrode voltage drop.

(2) The voltage drop per foot of tubing.

With a knowledge of these voltage drop components it is possible to predetermine the total voltage drop for any particular length of tubing.

The fact that the laws of current conduction along a gaseous path do not obey Ohm's Law led to the introduction of the high magnetic leakage transformer, the principle of which gives the equivalent of combining a choke coil with the step-up transformer. It is, of course, necessary to restrike the discharge at the beginning of each half-cycle and to control the current approximately constant during the remainder of the half-cycle. The striking of the discharge and current control is effected automatically by the use of the high magnetic leakage transformer.

It cannot be claimed that this is the ideal method of meeting the requirements because of the introduction of the high transformer inductive reactance into the circuit, which results in an appreciable reduction in the operating power factor. This type of transformer is, however, the one which is generally used for the supply of luminous discharge tubes. Other methods, such as the use of capacity and inductance to form a resonant circuit, have been tried and are, in fact, actually in use. There are, however, certain difficulties in the use of any form of resonant circuit for the supply of luminous discharge tubes and the system has not been adopted very extensively.

THE HIGH MAGNETIC LEAKAGE TRANSFORMER.

The English Electric Company manufacture a range of high magnetic leakage transformers, or

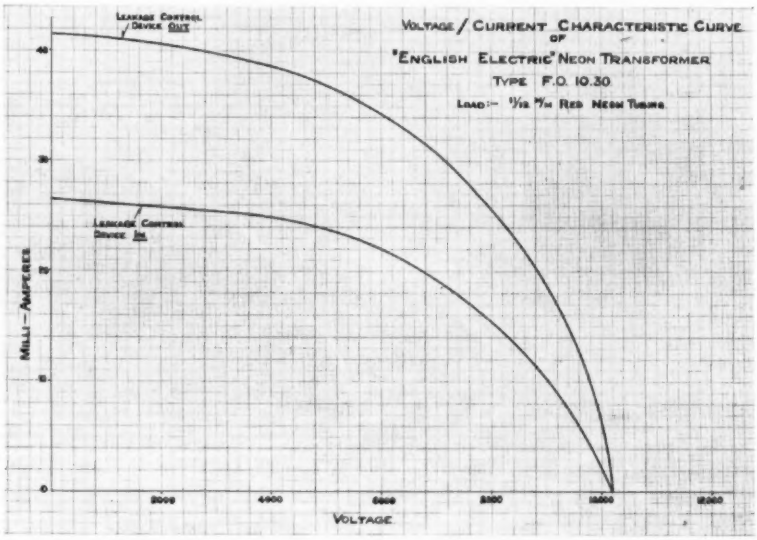

VOLTAGE / CURRENT CHARACTERISTIC CURVE OF "ENGLISH ELECTRIC" NEON TRANSFORMER
TYPE F.O. 10.30
LOAD:- 1/12 7/M RED NEON TUBING
LEAKAGE CONTROL DEVICE OUT
LEAKAGE CONTROL DEVICE IN
MILLI-AMPERES
VOLTAGE

Fig. 1.—Characteristic Curve of a 10,000 volts 30mA. Neon Sign Transformer showing range of Current Control.

as they are more popularly known, "Neon Sign" transformers, to meet all the normal requirements of the sign manufacturer. The Company also manufacture, to order, neon sign transformers for special applications such as aerial beacons.

The standard range of "English Electric" neon sign transformers include the indoor box type and also units which may be installed out of doors without any additional protection. The transformers are designed to have a high inherent reactance, and on certain of the outdoor type an adjustable magnetic leakage control device is incorporated, which can be locked firmly in the "set" position by a simple turn of an extended thumbscrew. The object of this device is to provide a means of varying the reactive choke value of the transformer and so control the secondary current output. A means is thus given for matching the luminosity of different tube lengths. In addition, the wide range of current output control allows the sign manufacturer to operate the tubing at the optimum current loading to suit his particular requirements.

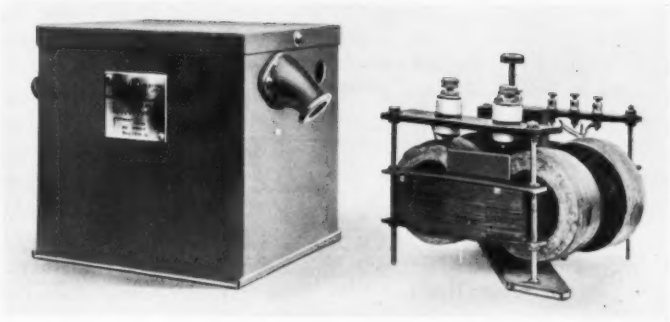


Fig. 2.— 10,000 Volts, 30 mA. output, Neon Sign Transformer Tank and Unit, Type F.O.10.30.

Fig. 1 illustrates a characteristic curve of a 10,000 V. 30 mA. unit, and clearly shows the range of current control.

In the case of outdoor units one of the most important points is that the unit must be perfectly weatherproof. To ensure this the tank lids are deeply lipped and care is taken that the terminal gland joints are a good fit so as to preclude the ingress of driven rain.

Fig. 2 shows a 10,000 V. 30 mA. output neon sign transformer tank and unit, type F.O.10.30. The accessibility of the external choke device may be seen and also the arrangement of the windings. It will be noted that the high and low-voltage windings are widely separated on the transformer core, ensuring that in no circumstances can the high voltage become superimposed on the low-voltage side. With this type of unit the mid-point of the high-voltage winding is brought out and connected to an external terminal on the transformer tank. In operation this terminal is connected solidly to ground and the transformer operates at a voltage above ground of one-half its normal secondary voltage.

After the transformer is tanked it is completely immersed in an insulating compound of high dielectric strength. Great care is taken in filling the transformer tank with compound to ensure that when set the compound is a homogeneous mass. The risk from small pockets of occluded air is twofold. Firstly, any small pockets of trapped air will ionise under voltage stress and, if adjacent to the windings, may lead to ultimate breakdown.

Secondly, these ionised air pockets may give rise to wireless interference troubles by acting as little broadcasting stations within the transformer itself. Any such trouble would not be curable by any form of capacitor or inductive filter device, the only remedy being to replace the transformer.

An interesting fact not always fully appreciated is evident from a consideration of the oscillogram shown in Fig. 3. This oscillogram clearly shows the initial striking voltage of short duration, followed by a voltage of approximately half the initial striking voltage for the remainder of the half-cycle.

It will also be appreciated that it is essential to design the neon sign transformer with sufficient insulation to ground to be capable of withstanding the full open-circuit voltage continuously. In view of the fact that the transformer is operating

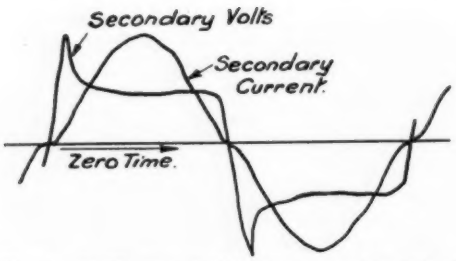


Fig. 3.—Oscillogram of high-voltage secondary side of a Neon Tube Installation, showing the flat-topped voltage wave.

at reduced voltage for the major part of the cycle, an attempt may be made to reduce the amount of insulation to ground. This would result in some small saving of insulation material, and hence in a slight reduction of cost. To cut the insulating clearances in this way is likely to lead to breakdown, especially under certain operating conditions. For instance, if the secondary circuit of the sign installation becomes open-circuited owing to a broken high-tension connection or faulty tube, the transformer is operating in the open-circuit condition.

In this condition the voltage stress to ground is the full open-circuit striking voltage which may continue for some time until the fault is discovered.

All " English Electric " neon sign transformers are tested to meet this possible condition by giving each transformer an induced over-potential test of twice the open-circuit voltage, maintained for one minute.

Noise Emission from Transformers.

The question of the silent operation of the transformer is very important. The noise takes the form of an objectionable hum at a frequency of twice that of the supply frequency. The high magnetic leakage characteristic of the transformer is a contributory factor, as there is a large magnetic leakage flux. In a badly designed transformer the hum may easily be audible 10 or 15 feet away.

The amount of noise is proportional to a large extent to the flux density in the core. In some designs an effort appears to have been made to reduce the cost to the minimum by cutting the cross section of the core, which results in a saving in the amount of iron and also in copper. The inevitable result of this practice, however, is to increase the flux density and, therefore, the noise, and in practice is obviously undesirable.

The tanks of outdoor type units should be sufficiently rigid to restrict any tank wall vibration and to minimise any tendency towards resonance between the magnetic flux alternations and the natural frequency of the tank sides.

In cases of transformers fitted with an adjustable current control device it is, of course, essential that means be provided to enable it to be firmly clamped into position after being finally set for the required current output.

Power Factor.

From the Supply Authorities' viewpoint the chief objection against the extensive use of neon sign installations is their low operating power factor. Without some special arrangement for metering such supplies the revenue from such installations is extremely small. The installation is, therefore, from the Supply Authorities' viewpoint, not very desirable or attractive.

To offset this disadvantage, it may be fairly claimed that a well-designed sign of good taste not only brightens the town, but is a valuable piece of propaganda for the use of electricity. Most Supply Authorities do, however, insist that some form of power factor correction be included in the installation. The apparatus usually installed for improving the operating power factor is static condensers and sufficient capacity is included to raise the power factor to 0.8.

It is well known that there are two main sources of power factor reduction in an electrical circuit :—

(1) The phase displacement of the current and voltage waves in time phase, as shown in Fig. 4.

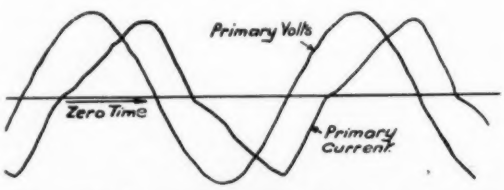


Fig. 4.—Oscillogram of primary volts and current in a Neon Tube Installation.

(2) The distortion of the current or voltage wave-forms from the sinusoidal.

In a neon sign installation both these forms of power factor reduction occur. It is quite an easy application in the case of the reduction of the power factor due to phase displacement to correct this condition by the introduction into the circuit of electrostatic capacity in the form of condensers.

The reduction of power factor due to wave-form distortion is, perhaps, not so well understood. An examination of the oscillogram shown in Fig. 3, taken on the high voltage secondary side of a neon sign installation, is interesting. It will be seen that the voltage wave-form is distorted appreciably from the sinusoidal wave-form, but is almost in time-phase with the current wave-form. A power factor differing from unity does, however, exist in the high voltage secondary circuit. Here, then, is a case of a circuit in which there is no phase displacement between the current and its applied voltage, and yet the ratio of watts to volt-amperes differs from unity.

The general conception of power factor is based on sinusoidal voltage and current wave-forms. In the simple case of sinusoidal voltage and current wave-forms Cos θ is termed the power factor. It is, of course, the constant angle between the vectors representing I and V, i.e., the angular phase displacement. In dealing with current and voltage having wave-forms distorted from the sinusoidal this simple relationship of power factor no longer holds. The angle between I and V is not a constant, but is itself a periodic function of time. In the simple case of pure sine wave-forms the power factor depends only on the load, since

$$\tan \theta = \frac{\text{Reactance.}}{\text{Resistance.}}$$

In the complex case the power factor depends not only on the load, but also on the wave-form of the voltage which supplies current to the circuit. A mathematical analysis of the distorted voltage wave-form shows that harmonics of high magnitude are contained in the circuit. The reduction of power factor due to the wave-form distortion depends on the magnitude of these harmonics and not on their relative phase. For the average neon tube installation the reduction of power factor due to this phase distortion is of the order of 10 per cent. It is not possible to correct for this source of power factor reduction by the addition of any form of reactance or electrostatic capacity in the form of condensers.

As already indicated, it is possible to correct the power factor reduction due to phase displacement by means of static condensers. It follows, therefore, that the usual formula for estimating the capacity of a condenser, $C = \frac{I}{2\pi fE}$ is only approximately correct, i.e., this simple relationship is only correct for sinusoidal wave-forms. The formula may, however, be used for estimating the capacity required to correct a neon sign circuit

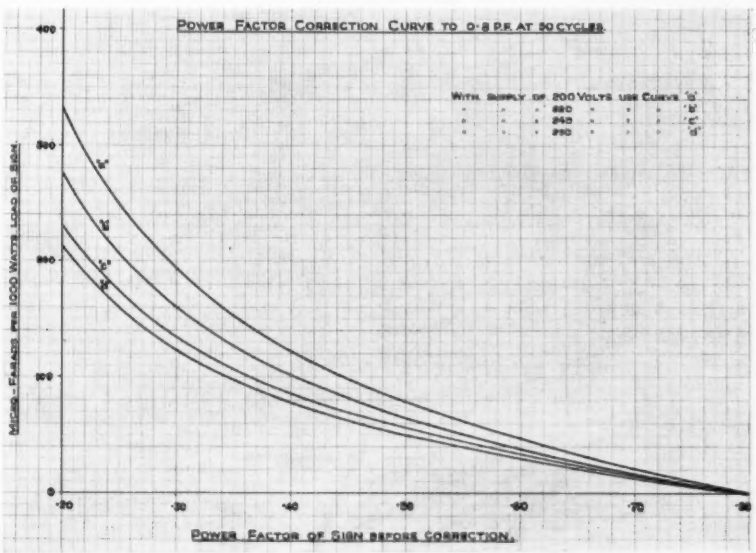

POWER FACTOR CORRECTION CURVE TO 0·8 P.F. AT 50 CYCLES.
WITH SUPPLY OF 200 VOLTS USE CURVE '0'
MICRO-FARADS PER 1000 WATTS LOAD OF SIGN.
POWER FACTOR OF SIGN BEFORE CORRECTION.

Fig. 5.—Curve plotting relationship between microfarad capacity per kilowatt of load and the power factor of a Neon Sign before correction.

to any desired power factor providing its limit of accuracy is recognised.

Fig. 5 gives a curve plotting the relationship between microfarad capacity per kilowatt of load and the power factor of the sign before correction. The curve may be used to calculate the approximate capacity required to be installed to correct a neon sign installation to 0.8 power factor as shown by the following example :—

Assume the watts loss of the sign installation, as measured by a wattmeter, is 700 watts. It is further assumed that the product of volt-amperes is 250 volts $\times$ 7 amps. = 1,750 VA as measured with a voltmeter and ammeter simultaneously with the wattmeter reading. Then the power factor being the ratio of watts to volt-amperes is 700/1,750 = 0.4. Referring now to Fig. 5* curve " d " for 250 volts and interpolating at 0.4 representing the power factor the value of 78 is read on the ordinate scale, representing the microfarad capacity per 1,000 watts of sign loading to correct the power factor to 0.8. The watts loading is 700, therefore, the microfarad capacity required is 78 $\times$ 0.70 = 55 m.f.

THE MOST ECONOMICAL LENGTH OF TUBING.

The ideal wave-form from an operating point of view would be flat topped along the " running " portion of the cycle. Such a wave-form would indicate that a long life may be expected from the tube and the transformer.

This desideratum can be controlled to some extent in the design of the neon transformer and by the liberal use of the active material. Any attempt to increase the flux density in the transformer core beyond a certain maximum would result in a transformer having inferior operating characteristics. In the same way to operate a transformer supplying the very maximum possible length of tubing is not to be recommended. The effect of operating too great a length of tubing is to induce high frequency oscillations near the peak of the open-circuit voltage of the transformer.

Such high-frequency oscillations place a severe strain, not only on the transformer, but also on the whole of the secondary circuit, which includes the neon tubing and the high-voltage wiring. The slight gain of operating, say, 3 or 4 per cent. more tubing is more than offset by the risk of appreciably shortening the life of the tubes and the possibility of breakdown.

Domestic Electrical Appliances—Recent Additions to the Range.

By W. A. GILLOTT, A.M.I.E.E., Sales Manager, Domestic and Heating Section.

The range of the Company's domestic and heating products has been extended in order that a wider market may be covered; this article is devoted to a brief description of the new products.

COOKERS.

Many electricity supply undertakings have found it necessary to exercise economy in the buying of cookers for hire and hire-purchase schemes. After careful consideration the Company have extended their well-known range of electric cookers known as the HC.201 to HC.206 series, which are cookers in the de-luxe finish, complete with various accessories and furnishings, by additional cookers designated the HC.1A, HC.201A and HC.206A. These follow very closely in general design the HC.1, HC.201 and HC.206 cookers. The difference between these two types is that the " A " series is complete with essential features only, such embellishments as splash plate, plate racks, removable crown plates, hot cupboard door, fuses on each circuit and oven bottom heat being omitted. It is thus possible to make an appreciable reduction in price and assist the supply undertaking in meeting competition from other forms of cooking apparatus,

* *Enlarged copies of Fig. 5 may be obtained on application by anybody interested and desirous of using them.*

Fig. 1.—Cooker No. HC.206A.

Fig. 2.—Cooker No. HC.206.

as a lower purchase price enables a lower hire charge to be made.

By supplying a cooker in this economical form a purchaser is enabled, if he so desires, to add the additional furnishings, which can be supplied individually. In general practice the supply undertaking, when purchasing cookers, decides which optional extras it desires to be fitted in line with local requirements.

An example of the HC.206A cooker is shown in Fig. 1; it consists of a hob containing an 8 in. and $6\frac{1}{4}$ in. boiling plate and a 10 in. $\times$ 7 in. grill boiling plate; all are arranged for 3-heat regulation and fitted with "plug-in" type connections. The oven is fitted with side-heating elements and the cooker furnishings consist of oven drip tin, three rod shelves, one grill pan and grid, and a polished deflector plate for sliding beneath the grill boiling plate when this is used for boiling only. It is thus cheaper than the 206 cooker illustrated in Fig. 2. It will be noted the two cookers are similar in appearance and, in fact, all electrical parts are interchangeable. The modifications referred to do not in any way affect the performance of the cooker, as its cooking capabilities are in no way changed.

On the "A" series of cookers all boiling plates and grill boilers are interchangeable, so that an Undertaking standardising on, say, three sizes of the Company's cookers need only carry a minimum stock of spares for replacement purposes.

The HC.201A and HC.1A cookers are illustrated in Figs. 3 and 4 respectively.

Breakfast Cookers.

To meet the demand for a cooking appliance which can be used for a small family or as an

Fig. 3.—Cooker No. HC.201A.

Fig. 4.—Cooker No. HC.1A.

auxiliary to a full cooking range, the Company has introduced a breakfast cooker, Catalogue No. HC.250. It is made of a cast-iron body cast in one piece, thus obviating joints and crevices in which dirt or fat could collect. The hob is also of cast-iron and the whole vitreous enamelled in a pleasing finish.

The grill boiler, which is interchangeable with the " A " series of cookers, provides a radiant form of heat, and enables cooking to be carried out on top of the plate or underneath either independently or simultaneously. As an example of its capabilities, a lunch for four persons consisting of chops or steak, potatoes, cauliflower, a sweet or stewed fruit, and coffee is prepared at the cost of one unit of electricity and a breakfast for four persons, consisting of porridge, eggs, bacon, toast and coffee is cooked at a cost of half a unit of electricity. The illustration in Fig. 5 shows the breakfast cooker complete with drop-down door and extension shelf, which may be added as an optional if desired.

Fig. 5.—Breakfast Cooker—Catalogue No. HC.251.

Electric Fires.

New electric fires added to the existing range comprise the coal-effect fire, Catalogue No. HH.150 ; sheet-metal fires, Catalogue Nos. HH.140 and HH.141 ; reflector fire, Catalogue No. HH.114 ; inset fires, Catalogue Nos. HH.142 and HH.143 ; and wall-type mantel fires, Catalogue No. HH.130.

The coal-effect fire illustrated in Fig. 6 gives a very realistic impression of live coal ; the flicker device produces the effect of flames rising up the chimney in a wavy motion, thus differing from the usual monotonous flicker as seen in the past. The actual coal effect is made of unbreakable glass silk. An important advantage of the Company's coal flame effect device is that the fires are shipped with all parts intact ; there is, therefore, no assembly to be carried out by the retailer prior to delivery to his customer.

The body of the fire is made of sheet-steel pressings ; the elements, which are of the Company's standard design, are made of first quality nichrome wire and interchangeable with any " English Electric " fires having bar type elements. The fire has a flat back, thus enabling it to be placed against a wall or a flat tile surround in a fireplace.

There are two standard finishes, oxidised bronze and oxidised silver, the switch knobs and element guards in each case being chromium plated. Each element can be controlled independently and the coal effect is controlled by switching " on " and " off " from the switch plug on the wall.

A new low-priced sheet-metal fire, available in 1 kW. and 2 kW. sizes (Catalogue Nos. HH.140 and HH.141) has been introduced. The fires are made of welded sheet-steel, making a very strong yet light fire. Although the fires retail at 8s. 11d. and 15s. 11d. for the 1 kW. and 2 kW. sizes respectively, the standard fire bars—using the first quality nichrome element—are employed. They are available in two standard finishes, Jubilee blue and gold and Marina green and gold.

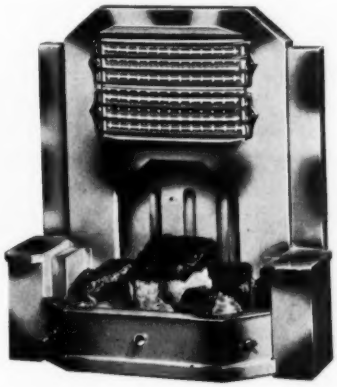


Fig. 6.—Coal Effect Fire—Cat. No. HH.150.

The fires are packed in cartons in order to facilitate handling by the dealer. A 2 kW. fire of this type is illustrated in Fig. 7.

An additional new model reflector fire is illustrated in Fig. 8. The supporting sides are in black crinkle finish and the parabolic reflector is polished chromium plate.

Examples of the Company's new inset type and wall type fire are illustrated in Figs. 9 and 10. Architects and builders will appreciate these new designs by reason of the fact that they readily assist in the building of modern houses. The installation of such fires eliminates a considerable amount of brickwork for chimney breasts, mantels, hearths, etc. In several instances even in the small artisan type of house, where in each of the two bedrooms an inset fire is fitted, the saving, after paying the cost of wiring and fitting the fires, is over £10 per house.

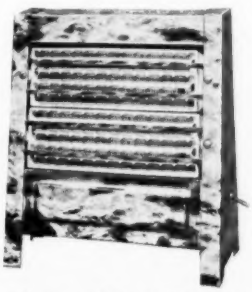


Fig. 7.—2-kW. Sheet Metal Fire—Cat. No. HH.141.

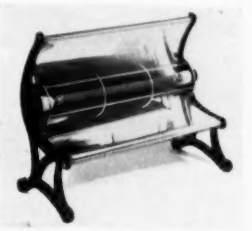


Fig. 8.—Reflector Fire—Cat. No. HH.114.

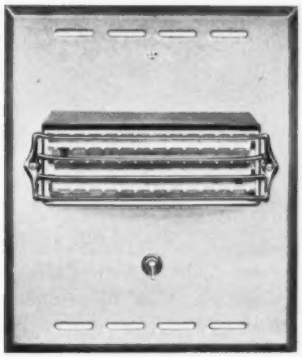


Fig. 9.—1-kW. Inset Fire—Cat. No. HH.142.

In designing this type of inset fire every care and attention has been given to transferring the heat into the room. The fire elements are mounted on the front frame, the fire back or box being a separate portion. Above the elements are suitable louvres and deflectors for directing the heat in an outward and upward direction, and at the same time providing adequate ventilation behind the fire, thereby keeping the back cool and safe.

The fires are so designed as to permit modifications in fitting to suit the building requirements,

Fig. 10.—Mantel Surround Fire—Cat. No. HH.130.

these details being carried out according to individual demands.

Water Heaters.

An addition has been made to the range of water heaters of the "Push" type by adding a water heater known as the HW.1001.

This water heater was produced to overcome to a large extent the trouble due to furring. Fig. 11 illustrates the interior complete with its apparatus plate. The design differs from the usual type inasmuch that the element is comparatively short, the element case being fitted with fins. The thermostat is placed in the cold water inlet pipe and extends to the top of the "U" pipe. Therefore, as soon as the cold water inlet tap is open, the cold water surrounds the thermostat tube and brings the thermostat into operation almost immediately; thus a more rapid recovery of temperature of the water in the container is produced. Generally speaking, drawing off a third of a pint of water is sufficient to close the thermostat with this type of water heater, whereas in the usual type some 5 to 6 pints of water must be drawn off before the thermostat operates; this is due to the thermostat being placed actually in the body of the hot water and often extended well up the tank.

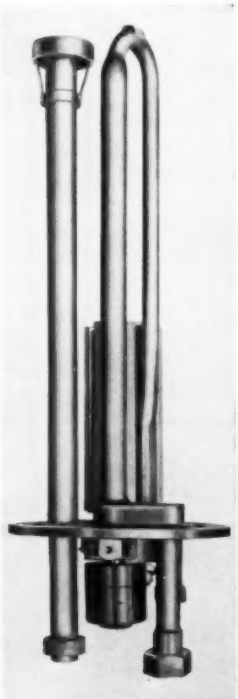


Fig. 11.—Interior of the 1½ gallon "push" type water Heater—Cat. No. HW.1001.

The short element of the HW.1001 type, with its outer casing fitted with fins, produces a slight circulation inside the tank; this action to a large extent equalises the temperature of the water, the difference being not more than 5 deg. F. between the bottom and the top of the tank, whereas in the ordinary type of water heater the variation is often as much as 40 deg. F. If the thermostat is set to 160 deg. F. in the HW.1001 type the water will eventually reach a uniform temperature approximately equivalent to the thermostat setting, whereas in the ordinary type with the thermostat at the same setting the temperature of the water would be approximately 140 deg. F. at the bottom, 160 deg. F. in the centre, and 180 deg. F. at the top. Such a wide variation is conducive to rapid furring in certain waters, whereas in the HW.1001 type furring is reduced to an absolute minimum.

The following results of a test may be of interest:—

One of the HW.1001 "Push" type 1½-gallon water heaters was put into operation with the thermostat set to 160 deg. F. When the water in the tank reached this temperature eight two-pint jugs of water were run off in succession and the average temperature was found to be 142 deg. F. This demonstrates the advantage of the quick closing of the thermostat and the good circulation of the water in the tank. The type HW.1001 water heater is recommended for general application and especially in "hard water" districts.

The Company's range of water heaters includes a 5, 12, 15 and 20-gallon pressure type. Cistern type water heaters in these sizes and of rectangular shape are now under construction and will be available shortly.

Electric Washing Machine.

After exhaustive tests the Company have put on the market an electric Washing Machine which may claim to be distinctive both as regards appearance and performance.

The exterior of the machine is square in shape; the washtub itself is circular, of porcelain enamelled finish and holds eleven gallons of water and ten pounds of dry clothes. It is supported and enclosed by the external square casing, a construction which provides adequate heat-insulating air space around the tub. Fig. 12 shows the machine with the wringer in position.

The washing mechanism consists of an easily removable three-winged rustless metal agitator fitted in the bottom of the tub. The driving

Fig. 12.—Electric Washing Machine, with Wringer mounted in position—Cat. No. HA. 333.

shaft, on to which the agitator is fitted, operates through a rubber gland, which, in addition to ensuring water-tightness, also eliminates vibration and possible noise when the machine is running.

The wringer is a self-contained detachable unit with an all-steel unbreakable frame which combines exceptional strength with rigidity and lightness. The rollers are 14 in. long × $2\frac{1}{4}$ in. diameter and are made of high quality soft rubber, which extract the maximum amount of water when wringing. A central pressure screw ensures that an even pressure over the whole length of the roller is obtained, a patented simplified safety release, which is automatically resetting, is incorporated. The wringer can be locked in any of six positions.

Power for driving the agitator and wringer is provided by one of the Company's standard single-phase motors having an output of $\frac{1}{4}$ h.p., with a speed of 1,425 r.p.m. It can be wound for any

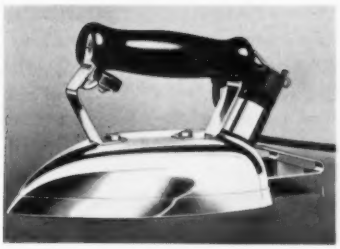


Fig. 13.—Streamline Electric Iron—Cat. No. HA. 310.

voltage up to 250 volts for a 50-cycle alternating current supply, the general standard voltages being 200/220 and 230/250.

Remarkably silent operation of the washing machine has been obtained by the design and construction of the driving motor together with its special resilient mounting; all auxiliary gears are machine-cut and special consideration is given to the assembly of all moving parts.

The starting and control of the machine is extremely simple. The starting lever is conveniently placed at the front, and it is arranged that the wringer and the agitator can be used separately or both at the same time.

All external parts are finished in high-grade enamel in attractive shades of cream and green, and all metal parts are cadmium plated.

Electric Iron.

Fig. 13 illustrates the Company's new streamline electric iron. It embodies features that scientific research has evolved to make ironing faster, easier and better; the adjustable thumb-rest and " natural slope " handle help to eliminate

Fig. 14.—The Handidrier—Cat. No. HA. 300.

fatigue. A bevelled edge is provided all round the iron, which, together with the correctly tapered point, enables the user to iron with ease around buttons and tucks.

The connector is of the side-entry type so that the flexible is held out of the way ; it is available for right or left hand working.

External metal parts are heavily chromium plated, the weight of the iron is 5½ lbs. and the consumption 500 watts.

HANDIDRIER.

An illustration of the Handidrier is shown in Fig. 14. The Handidrier is ideal for drying light articles such as gloves, stockings and handkerchiefs. Articles may be dried in perfect safety because the Handidrier does not glow, and drying is effected solely by hot air currents.

It is beautifully finished and the construction is such that articles of varying lengths can be easily accommodated by adjustment of the supporting rod.

The Electrical Equipment of Trolley Vehicle Routes.

Reprint of Paper read before the Tramways and Light Railways Association at Llandudno, 6th June, 1935.

By J. E. CALVERLEY, M.I.E.E., Chief Engineer and Manager, Traction Department.

INTRODUCTION

By L. H. SHORT, M.C., A.M.I.E.E., A.M.Inst.T., Assistant Manager, Traction Department.

It has been the aim of this Paper to make some suggestions on a few of the points which arise on the installation of, or conversion to, trolley bus operation. The particular points dealt with are mainly those in connection with the supply of power to the vehicle. The decreased conductivity of the overhead system, together with the higher schedule speeds maintainable with the trolley bus as compared with the tramcar, have given prominence to the mercury rectifier sub-station as being an economical and convenient means of avoiding heavy expenditure on copper.

Then the increasing popularity of regenerative control gives rise to problems both on the supply side and on the vehicle. The former has to be dealt with whether the power is derived from rotary plant or rectifiers ; the latter involves the matters of over-voltage and loss of braking power.

Wireless interference has received a great deal of attention and opinions vary as to the efficacy of the means of suppression. Finally, the trolley bus has been responsible for developments in the connecting link between power system and vehicle, namely, the collector head.

TROLLEY BUS AND TRAMWAY OPERATING CHARACTERISTICS.

The main differences as stated in the Paper are :—

(a) Decreased conductivity of railless distribution system, due to the absence of the track return.
(b) Maintenance of higher schedule speeds by trolley buses.
(c) The greater use of regenerative control on trolley buses.
(d) The mobility of the trolley bus.

No particular comments are needed on the above, except, perhaps, to mention a few figures on schedule speeds. A tramway service will in general be operated at between 7 and 8 m.p.h., and in exceptional circumstances reach 10 m.p.h. This latter figure is moderate for the trolley bus, which is capable of 12 m.p.h. and more ; and a 15 m.p.h. schedule is not unknown.

The result of these increased speeds is that the trolley bus is proving a very successful competitor with other forms of transport in outlying districts, so that operators should no longer be content

with allowing a relatively large drop in line voltage at the end of such routes. Everything should be done to take advantage of the trolley bus's characteristics. It is, therefore, worth while paying attention to the question of conductivity, since this factor is approximately halved with the railless system. In the first place, it will be realised that the copper on a tramway is practically confined to the positive side of the overhead system, whereas it is shown in the Paper that the most economical distribution for the trolley bus is when it is evenly divided on the two sides.

On double-track routes it is also desirable to tie in together electrically, like pairs of trolley wires. While the saving is obvious in extreme cases, the degree as given in the Paper may be of interest. Obviously with one bus at the end of a stub-end feed the conductivity is doubled if it can draw current over two trolley wires, whereas there would be little gain if a number of buses were spaced end on end on each track.

The use of distributors as distinct from feeders is probably not common in this country. By feeders are meant cables from a source of power to some definite point on the overhead trolley wire, whereas distributors are cables running parallel to, and electrically connected at intervals, to the trolley wire. The distributor formulæ given in the Paper are intended to show that they virtually increase the cross-sectional area of the trolley wires. Hence, in considering any route to be installed or connected, a convenient starting-point may be found in the conductivity required for the distance and traffic density concerned.

The chart gives the conductivity in terms of copper additional to that of the trolley wire, and this, of course, represents a certain amount of money.

If it is a question of conversion, the additional copper can be compared with existing facilities such as feeders. Feeders will, of course, sub-divide the length of route, but it must be remembered that in general the feeders will have to be duplicated on the negative side. The aim will, of course, be to eliminate additional copper, and, in view of the possible heavy expenditure of copper, whether as feeders or as actual distributors, it will often be found better to install a sub-station ; that is, better not only financially, but in the matter of convenience and in making provision for the increase in traffic which seems invariably to follow the conversion to trolley bus operation. Thus any increase in traffic will cause a heavier voltage drop in a cable whose

Fig. 1. One of a fleet of "A.E.C.-English Electric" 60-seater Trolley Buses in service at Bradford.

capacity is probably limited ; on the other hand, the rectifier sub-station affords a most convenient means of overcoming this difficulty, on account of the advantages enumerated later, and, in addition, the comparative ease with which their capacity can be increased, particularly in the case of the glass bulb rectifier.

There is a further point to mention : the conversions to trolley bus working are often contemplated when tramway renewals are due ; the expenditure on a new track is a heavy item and its avoidance outweighs the cost of increasing the conductivity of the overhead system.

There is one point to bear in mind in connection with what has been termed the average current of a vehicle, namely, that the performance of a modern vehicle will not appreciably affect the figure suggested in the paper as 40 amps. This is because the lower consumption is offset by the higher schedule speed maintained ; thus, values of 1.7 units per bus mile at 500 v. and a schedule speed of 12 m.p.h. gives an average current of 41 amps.

This section can therefore be summarised by saying, first, find the conductivity required and then reduce the additional copper either by the installation of sub-stations, or by the use of existing feeders ; the area of the distributor copper, which is obtained from the chart, providing a datum line when estimating the alternatives. It will probably be found more useful to redraw the chart for double-track conditions and make such other adjustments as may be found desirable for any particular system. It is noted that in the printed copy of the paper the squares of the original paper are not reproduced, but the author will be pleased to send a copy of the original curves to anyone who is interested in this question.

Battery for Propulsion Purposes.

Where faulty sections can be isolated it will be advantageous to provide for movement of the vehicle in the absence of a supply of power on the overhead line, and it is of interest to mention a recent development in the equipment of the trolley bus, designed to increase its mobility, namely, the use of the lighting battery for propulsion purposes. A foot-operated push-button is provided, which energises a contactor connecting this battery to the traction motor armature and series field only. Under these conditions the vehicle can be propelled at about 3 m.p.h. on the level, drawing from 40 to 50 amperes from the battery. Starting with a fully-charged battery, it has been found possible to run a bus over a distance of more than a mile on the level. The use of this equipment extends beyond depot and turning-circle manœuvres, for it enables a bus to circumvent road obstructions or a faulty section of overhead, and thus maintain full continuity of service.

The use of the feature of being able to " jump " a section is, of course, limited by the gradient, but in any case it will be realised that no trolley bus vehicle, short of breaking an axle or wheel, need remain an obstruction in the middle of the road. The use of the battery outlined above may appreciably lessen the inconvenience caused by the above mishap.

Regeneration.

While regeneration is becoming increasingly popular, it is not, of course, universal. Its development is due largely to those systems where gradients are exceptionally severe and where brake wear has consequently been very heavy. The latest form of regenostatic control, that is, regenerative and rheostatic, provides a transmission brake which is particularly suitable to the variable conditions of the road surface in bad weather. This brake, moreover, is so arranged that it is impossible to overstress the driving mechanism. The best use of the regenerative system is obtained when all the current is absorbed by other buses operating at the time, for the local circulation of current in the overhead system is then really a gain in conductivity and energy consumption. On level routes the percentage regeneration may be reckoned at about 10 per cent.

The isolation of sections of the overhead should therefore be specially considered in relation to this matter. In outlying districts through feeds are desirable, and here again there are grounds for considering the merits of the rectifier. The rectifier, however, introduces the problem of over-voltage, as it cannot accept reverse current.

Over-voltages cannot be tolerated on a 'bus—

on the lighting circuit, for instance—yet at certain times and under certain conditions the line voltage will tend to rise. As an example, one has only to consider the first bus out or the last bus into a depôt. A bus must also be protected from loss of braking following no-volts on the line, and this can be dealt with in two ways, or preferably by a combination of the two. In a rectifier station relays can be provided which insert resistance across the line, thus providing a load for regenerated current not otherwise absorbed. The most satisfactory protection, however, can be provided on the bus itself by the provision of an over-voltage relay. In the event of the terminal voltage of the regenerating motor rising above a pre-determined figure, connection to the line is broken and the motor circuit is automatically changed to rheostatic braking.

It is of interest to note that such increased duty has not been found detrimental to, nor does it call for increased size of, the rheostats. This is due to the fact that they are rated for service under fog conditions, and this approximates to the requirements of full rheostatic braking.

The feature does not introduce any complications into the control of the bus so far as the driver is concerned, as the relay operates in emergency automatically and independently of the controller, maintaining the same rate of braking.

Sub-Stations.

There is no doubt that the increasing availability of power in outlying districts due to the grid and local extensions will have a beneficial effect on the development of this form of transport, for it is now economical to install small rectifier sub-stations without undue expenditure in cable on the A.C. side.

The rectifier possesses the advantages of silence, compactness and economy of foundations and buildings. It is obtainable in small sizes and can readily be duplicated, and in this connection it is worth remembering the advantages of having standard bulb sizes and spares in general.

Another advantage is the fact that they lend themselves readily to automatic control. This, in conjunction with the fact that they do not normally take regenerated current, makes them suitable for parallel operation, possibly directly connected to the line. Parallel operation means that the rectifiers can be operated without undue complication, according to traffic demands, and at the same time permit continuity in the overhead system for the better absorption of regenerated current by other buses.

It may be mentioned that for preliminary calculations the installed capacity in kilowatts for a given system may be reckoned as half the aggregate horse-power of the motors operating.

Control.

It is not necessary to enlarge on this section of the Paper except to comment on the possible criticism of the locking-out feature. After all, if there is a bad fault, necessitating a shut-down, the overhead or traffic staff are not likely to walk out to the scene—they will have a car, which is equally convenient in reaching the sub-station affected. Any unnecessary complications are to be deprecated.

Fig. 3. "A.E.C.-English Electric" Trolley Bus in service at Kyoto, Japan.

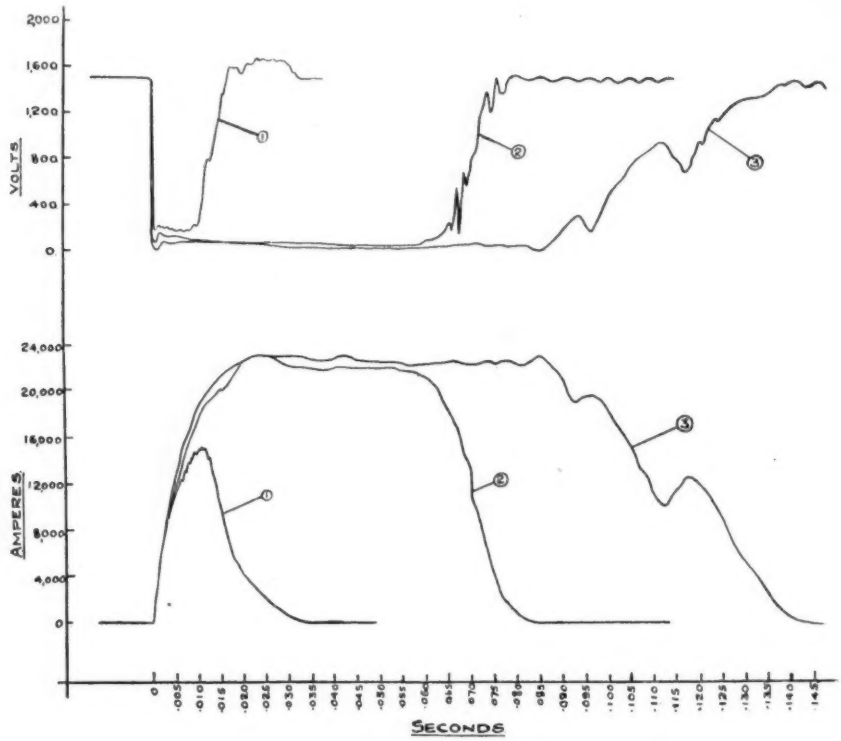


Fig. 4. Illustrating technical differences between high-speed and medium-speed circuit breakers.

Characteristics.

The normal shunt characteristic of the rectifier is all that is required on traction work, for compounding will only lead to a station tending to grab available load.

Protection.

As regards high-speed and medium-speed breakers, apart from cost, the former take up more space and require separate mounting, the size of the latter will vary according to whether a steel tank or glass bulb rectifier is used. The illustration (Fig. 4) gives a fair idea of the technical differences, curve (1) corresponding to the high-speed breaker and curve (3) to the normal type. The intermediate curve is for a contactor type of breaker, with which we are not concerned.

In regard to lightning protection, this is a subject of which very little useful date is available, for the reasons stated, but, in view of the fact that trolley buses are now being installed in all parts of the world, the problem requires still closer investigation. The nature of lightning and the variation of its effect, due to local conditions, however, makes it impossible to forecast the efficacy of any particular protection with any degree of accuracy, and one must therefore await results in operation. The additional protection, for instance, of two 0.5 microfarad condensers provided with horn gaps, connected across the positive and negative wires, with mid-point earthed, appears likely to be effective, and since this arrangement is similar to one suggestion for the suppression of wireless interference, spacing

these groups at quarter-mile intervals along the line makes an economical application.

Wireless Interference.

In spite of the tremendous amount of work that has been done by many people, there is still a great variation in opinion. Supporters will be found for most of the methods mentioned in the Paper, but others will have found no difference at all arising from their use. Anything that affects the senses is notoriously difficult to deal with, but progress is being made with the setting up of standards based on field strengths at various distances from the trolley wires.

Application to the trolley wires alone of means to suppress interference has been tried on the Continent, but without great success, due to poor earthing, but it is proposed to equip a trial route with condensers in this country, where preliminary experiments have been found promising. The spacing will be reduced to one-eighth of a mile, and the relative cost of so equipping a mile of double track appears to be between 2 and $2\frac{1}{2}$ times that of fitting one bus with a pair of choke coils.

The evidence available, however, seems to be favourable to the choke coil as a satisfactory and sufficient suppressor. In view of the large number of buses already operating, it is most desirable to have some means which can be easily and cheaply fitted. This, of course, is the objection to some of the alternative means, for they entail more work in installation, except during the construction of a new vehicle.

The only objection to the choke coil in the past has been that its effectiveness has been limited to the short wave band. This difficulty has now been overcome, and choke coils are available to deal with usual broadcast frequencies.

Current Collection.

In addition to considerations of wireless interference, the adoption of the slider head in preference to the wheel is due to a number of other reasons, as follows :—

(1) Reduction of noise. Since the trolley bus is comparatively silent, noises hitherto unnoticed become magnified and cause undue annoyance. Such is the case with trolley wheels.

(2) Practically sparkless collection. This is advantageous both to trolley wire and slider, for pitting is a defect of the wheel. The slider and wire should acquire a well-burnished surface.

(3) Dewirements less frequent. The average figure for wheels appears to be about 6 per 10,000 miles for trolley buses as against 1 per 10,000 miles for the tramcars. The slider has reduced the trolley bus dewirements to approximately the latter figure.

(4) Lightness. The shoe is about 30 per cent lighter than the wheel and the renewals cost less.

The key to successful slider-head operation is lubrication, and considerable research is being undertaken in this country with a view to finding the most satisfactory arrangement. Self-lubricating heads are now on test, but it is too early to say whether these are completely successful. Of the external methods, the spraying of graphite in a volatile solution has been tried out, generally with satisfactory results, and fuller tests, which the trolley wires are brushed with oil from a tower wagon, are now being undertaken.

The problem of line lubrication is, of course, prominent on railway electrifications, where anything of a greasy nature is not considered favourably. This is because so much dirt gets mixed with the grease, especially where the traffic is interspersed with steam engines. It will, therefore, be of interest to follow these experiments on trolley bus systems throughout a year and hear whether the dirt and dust off streets has the same detrimental effect as the cinders and sulphur from the steam engine.

As far as can be ascertained, the life of a slider shoe is of the order of 2,500/3,000 miles for the positive shoe and 2,200/2,500 for the negative.

A number of materials have been tried out as inserts in the slider head, but the most satisfactory results to date have been obtained with special grades of cast iron.

ACKNOWLEDGMENTS.

In conclusion, the author wishes to thank his many friends in the transport world and other branches of the electrical industry for valuable information and the help given, and in particular to officers of the London Passenger Transport Board and Bradford Corporation Tramways.

THE ELECTRICAL EQUIPMENT OF TROLLEY VEHICLE ROUTES.

SYNOPSIS.

The extensive change-over from tramcars to trolley buses which is now taking place, together with the equipment of additional routes, makes investigation necessary into the methods of transmission and supply of power to the vehicles, and it is opportune at the present time to examine the various problems which arise in order to arrive at the best layout of the system.

One of the chief differences is the decreased conductivity of the trolley bus overhead circuit, as compared with the tramway system, and this factor is of great importance in deciding whether to use more copper or to install additional sub-station plant. The tendency is toward the latter course, and the advantages of the mercury-arc rectifier merit consideration.

The operating characteristics of the trolley bus itself tend to modify former practice and introduce new problems. Regenerative control is now recognised as standard equipment, and provision must be made for its use, particularly when the power is supplied through rectifier plant.

The subject of wireless interference has become prominent, and from this point of view the recent improvements and tendencies in the matter of current collection are considered, and some reference is made to the probable advantage of slider heads for current collection.

I.—TROLLEY BUS AND TRAMWAY OPERATING CHARACTERISTICS.

A clear appreciation of the outstanding differences between the two types of vehicle is the key to a satisfactory distribution system, more particularly so where there is to be a change-over from tramway to railless operation. While the trolley bus system is free from the problems of a ground return, such as electrolysis, bonding and the statutory limitation of volts drop, other differences arise, which may be stated briefly as follows :—

(a) Decreased conductivity of the railless distribution system.

(b) Maintenance of high schedule speeds by trolley buses.

(c) The greater use of regenerative control on trolley buses.

(d) The mobility of the railless bus, which in the case of a breakdown rarely leads to a general hold-up of the service.

Accordingly, it is necessary to concentrate attention on the following points :—

(1) To make as full use of overhead conductivity as possible.

(2) To have sections of overhead which are or can be readily isolated in the event of faults developing.

(3) To maintain good voltage regulation.

To a great extent the first two requirements will be found to oppose each other.

II.—CONDUCTIVITY OF DISTRIBUTION SYSTEM.

On the assumption that the resistance of the tramway track is one-eleventh of the corresponding trolley-wire resistance, it will readily be appreciated that the conductivity of the trolley bus overhead system is only some 54 per cent. of that of a normal track return tramway system. In considering a change-over from one system to another, it will usually be found that the tramway distribution system will be characterised by a number of positive feeders, and a lesser number of negative feeders, the runs of which do not coincide.

Now it can be shown that for a minimum

amount of copper the total volume should be equally distributed on the positive and negative sides ; thus, to reduce the resistance of a given section by 25 per cent., one-third more copper must be added if equally divided as against a 50 per cent. increase if confined to one side. It is therefore clear that if the same system of distribution is to be continued for the trolley bus, the copper will have to be increased on the positive side, and then duplicated on the negative side to obtain similar results. To avoid this possible heavy expenditure on copper, there is a tendency to install a larger number of sub-stations, and the problem is to find the most economical and satisfactory combination.

Fig. 5.—"A.E.C.—English Electric" Trolley bus as supplied to Huddersfield Corporation.

The usual tramway practice is one of isolation so far as sub-stations and feeders are concerned, for the sub-stations are not usually run in parallel and the portions of the route served by separate feeders are kept isolated from one another. In localities where the traffic is exceptionally heavy, separate feeders are run to the individual half-mile sections, which are accordingly isolated.

The most important consideration in congested districts is that of continuity of supply and speedy localisation of faults, and this requirement in the case of a trolley bus system may lead to the isolation of up and down tracks in the areas concerned. On the other hand, in outlying districts, where the service is lighter, full advantage should be taken of the overhead conductivity in all directions, and it is of interest to note the loss of conductivity resulting from isolation of up and down tracks. Under M.O.T. Regulations the overhead system must be sectionalised at half-mile intervals, the section pillars providing the means of paralleling like wires on the two tracks. In such cases, by reason of the fact that with a regular service the farthermost and nearest buses are equidistant from their respective ends, the total load may be represented by a constant drainage current.

If I = average current per bus,
d = route miles considered,
R = resistance per mile of either positive or negative side alone, and
n = number of buses in one direction only,

then the maximum voltage drop at the farthest bus is given by—

$$V = 2n \times \frac{R}{2} \times d \times I$$

It will be noted that this result is independent of the distance that the farthermost bus may happen to be from the end of the route.

If the two tracks were isolated, then the maximum drop would occur when a bus is at the end of the track, and the voltage drop is accordingly—

$$V = (n + 1)\, R \times d \times I$$

For equal voltage drops, and substituting Rs for the single track resistance and Rd for the double track—

$$Rd = \frac{n + 1}{n} Rs$$

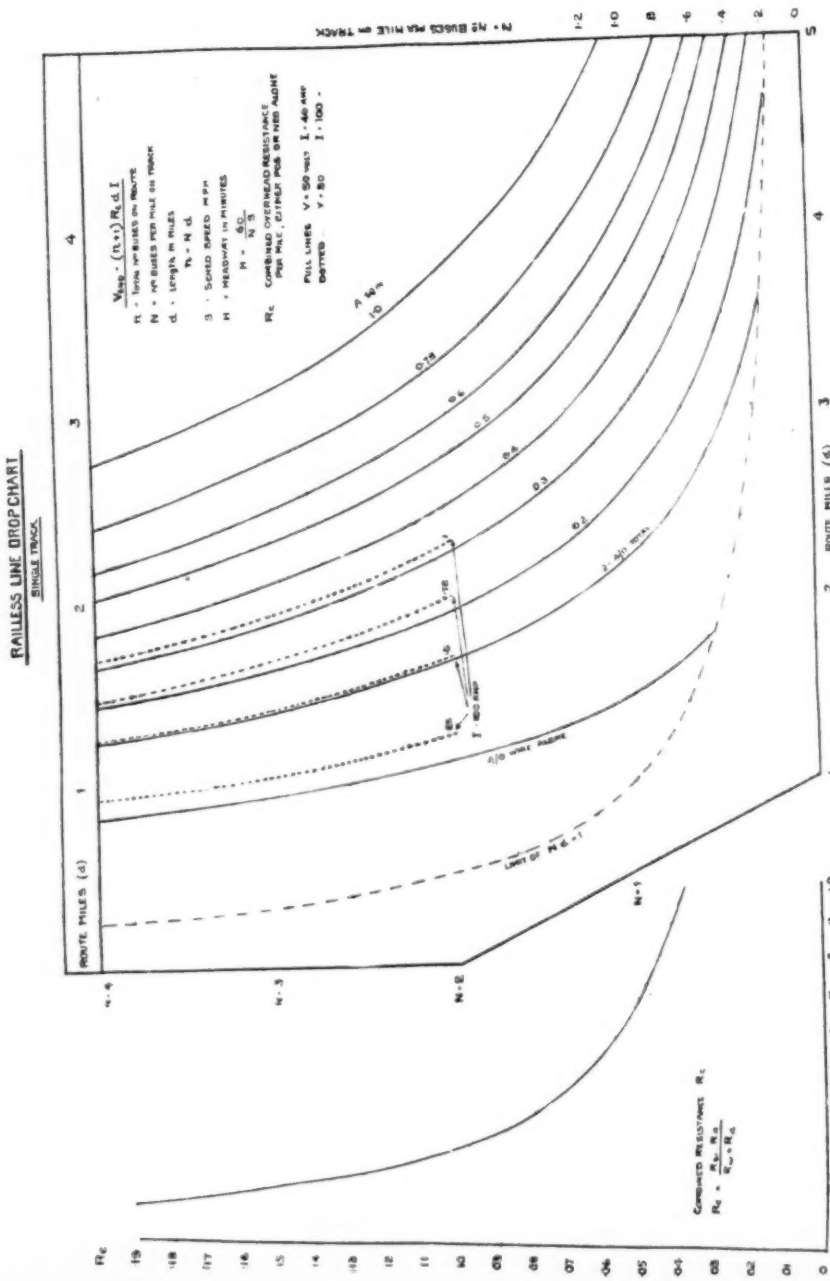

RAILLESS LINE DROP CHART
SINGLE TRACK
ROUTE MILES (d)
ROUTE MILES (d)
N = 4
N = 3
N = 2
N = 1
Limit of N d = 1
4/0 wire Aldrey
2 - 4/0 wires
Full lines V = 50 volts I = 40 Amp
Dotted V = 80 I = 100
Combined Resistance R_c
$R_c = \frac{R_b \cdot R_o}{R_b + R_o}$
DISTRIBUTOR SIZE 2/0 M (A)

Fig. 5.—Railless Line Drop Chart, for Single Track Working.

and since resistance is inversely proportional to the area—

$$\frac{Ad}{As} = \frac{n}{n+1}$$

The saving is thus found to be $\frac{100}{(n+1)}$ per cent.

If H = headway in minutes,
S = schedule speed in m.p.h.,
N = number of buses per mile, in one direction,

then $N = \frac{60}{H \times S}$

Taking for comparison a half-minute headway, with one of six minutes, the schedule speed being 10 m.p.h., the saving is 7·7 and 50 per cent. respectively, from which it is evident that the relative importance of conductivity from this aspect decreases with increase of traffic.

The use of distributors paralleling the overhead system and connected to it at the half-mile section pillars is sometimes adopted on tramway systems, and while such a scheme is more economical of copper, because fewer feeders are required, in the event of a feeder defaulting a larger area is affected. So far as this method of distribution is concerned, it will be appreciated that the drop at the end of any section is not necessarily the maximum drop, as current is fed into the trolley wire from each end of the section. It can be shown, however, that for ordinary purposes of computation the error is small if the drop at the end of a section is assumed to be the maximum.

Thus let d = length in miles of a trolley wire to which a distributor is attached at half-mile intervals.
n = number of buses on this length d.
I = average current per bus.
Rd, Rw = resistance per mile of distributor and trolley wire respectively.

Also, let x be current entering any half-mile section of trolley wire, and y the corresponding current in the distributor, then $x + y = C$, the total current to the section and to other sections, if any, beyond.

$$\text{And } y = \frac{Rw}{Rd + Rw}\left(C - \frac{n - 2d}{4d} \cdot I\right)$$

and the drop at the end of any half-mile section is—

$$V = 2y \cdot \frac{Rd}{2} = \frac{Rw \times Rd}{Rw + Rd}\left(C - \frac{n - 2d}{4d} \cdot I\right)$$

This formula can be applied to obtain the correct distributor size for equal voltage drops, i.e., graded distributor.

As an example, consider a two-mile length of single track, with 24 buses distributed along it ; if Rd = ·027 and Rw = ·347 ohms per mile, it will be found that the voltage drop at the end of each successive half-mile, and the maximum voltage drop in each section, assuming I = 40 amps., are as follows :—

Section.	1	2	3	4
Volts drop at end	21·5	37	46·5	50
Max. volts drop	23·8	41·1	52·3	58·7

The above is by way of being an extreme case to illustrate the point that half-mile sectioning provides sufficient points of contact to enable one to give the overhead system, with its distributors, a combined resistance, as though it were a single conductor.

Thus, the value of Rc in the equations

$V = (n + 1)\ Rc \times d \times I$ for single track

and $V = 2.n.Rc.I.$ for double (tied) track

may be taken as the resistance of the trolley wire or wires, or combined resistance of trolley wire and distributor, when distributors are used.

Having regard to the many possible ways of feeding a system, it will be useful to have some simple relationship between traffic density and conductivity for a given service and route. For this purpose the distribution requirements are given in terms of copper area, which can then be compared with existing or proposed facilities, in considering whether to use distributors, or substations, or a combination of both. The accompanying chart Fig. 5 may be found helpful for this purpose, being based on the considerations discussed above.

Service conditions are commonly specified in terms of headway and schedule speed. Since these values can be related to the number of buses per mile of track, the ordinates of the chart really represent traffic density.

The average power consumption per bus for

all undertakings appears to be about 2 units per bus mile (Garcke, 1934-5). This figure is obviously high for modern regenerative equipments, but it is a general figure which covers old or modern vehicles of all types. Assuming an average schedule speed of 10 m.p.h. and a potential of 500 v. on the line, the average current approximates very closely to 40 amps. per bus under all normal conditions and with any number of buses in service. A typical speed-time curve will show starting peaks of 250 to 300 amps., falling to 100 amps., and it may therefore be advisable to use this latter figure under certain circumstances. But for purposes of general calculations, where a number of buses are operating, it has been found satisfactory to assume that of every four, one is starting, another is at rest, and two are running. In view of the fact that, of the two running, one may be regenerating, the figure of 40 amps. does not appear unreasonable, and the use of this figure in practice has given reasonably accurate results. This value of current should, of course, be associated with the maximum number of buses which are likely to operate at any one time on the route concerned.

The chart has therefore been based on the equation—

$$V = (n + 1)\,Rc \times d \times I$$

in which V has been limited to 50 volts, and I assumed to be 40 amps. Thus, if a three-minute service is operating at a schedule speed of 10 m.p.h. over a route three miles long, giving N = 2, the chart shows that the extra copper required, in addition to the trolley wire, is 0.6 sq. in. to be added to both positive and negative sides.

The single curve on the left-hand side of the chart gives the combined resistance of one trolley wire with various cable sizes in parallel. The chart may also be used for a different value of average current, as determined by local conditions or found desirable, and the results corrected to suit. For this purpose the size of feeder is found, for I = 40, as before; the corresponding value of Rc is obtained from the left-hand curve. This figure, multiplied by the ratio of 40 to the current required, will give the new value of Rc, and the required figure for A is then obtained from the curve.

* For double-track trolley wires which are tied together, the value of Rc obtained from the left-hand curve should be multiplied by the factor $\frac{n + 1}{2n}$ The new value of A corresponding to this reduced resistance Rc includes the second trolley wire, which should accordingly be subtracted (0·12 sq. in.). The result is the net additional copper to be added to each side, as a common distributor.

For an outlying service, five miles long, on which the headway is 15 mins., and schedule speed 10 m.p.h., N = 0·4. The chart gives a 0·4 sq. in. distributor, the resistance of which, in combination with the trolley wire, is 0·081. The value of n = Nd = 2, and therefore $\frac{n + 1}{2n} =$ 0·75. The new value of Rc is therefore 0·061, for which the left-hand curve gives A = 0·57.

Fig. 6.—Two 120 kw. Glass-Bulb Rectifiers mounted in Cubicles.

**A Railless Line Drop chart for Double (Tied) Track working may be obtained on application.*

Subtracting 0·12 sq. in., the net additional copper to be added to the positive and negative sides as a common distributor is 0·45 sq. in. The additional quantity of copper represents approximately 40 tons. The voltage drop in the trolley wire alone, without this copper in the distributors, would be approximately 140 v., and it is obvious that either the required distributor area must be used, or else other arrangements made. This would appear to be a good case for a rectifier sub-station, as the cost of distributor copper alone would more than pay for the station. The voltage drop would be much improved ; even if the sub-station were located at the outer terminus the voltage drop would be in the neighbourhood of only 35 volts. The chart can also be used for sections which are fed from both ends, keeping in mind that the voltage drop of 50 v. is then approximately quartered.

In summing up the above considerations we find that in outlying districts full advantage should be taken of the overhead conductivity by continuous feeding through sections. It is also practicable to consider locating rectifier sub-stations along such a route, operating them in parallel and thus eliminating any copper additional to the trolley wire.

Continuity of supply must be the main objective in congested districts and this is best assured by the practice of isolation to a degree depending upon local circumstances. Since the traffic is presumed heavy, the scope for the absorption of regenerated current is not reduced, and it has been shown that the loss of conductivity is not serious under these conditions.

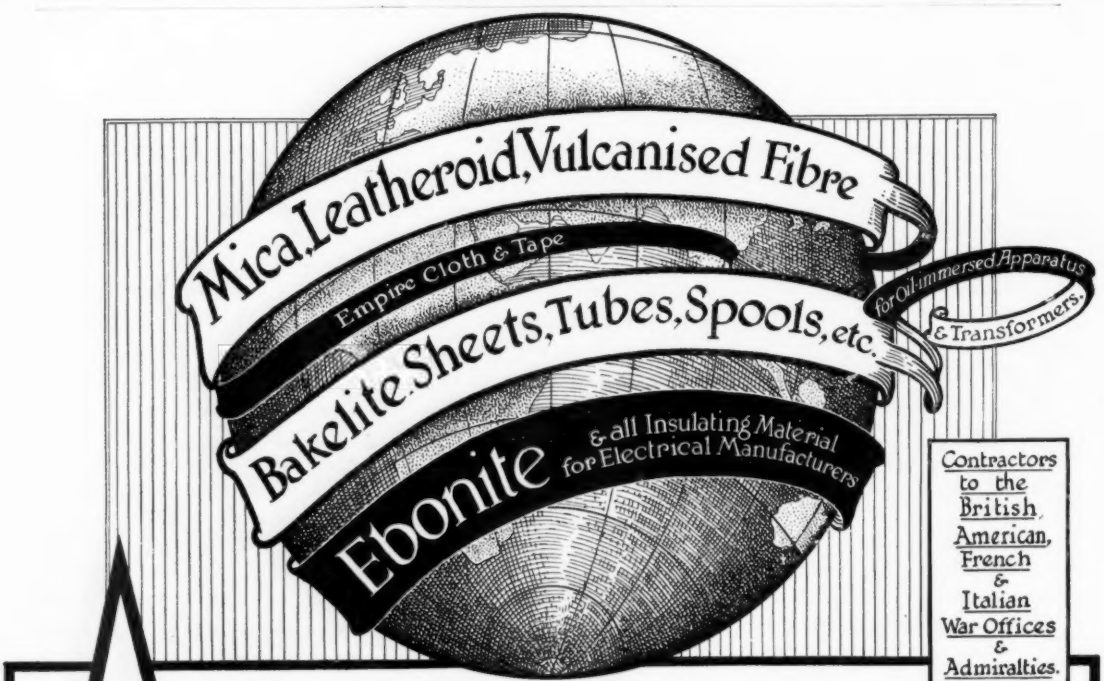
Where faulty sections can be isolated it will be advantageous to provide for movement of the vehicle in the absence of a supply of power on the overhead line, and it is of interest to mention a recent development in the equipment of the trolley bus designed to increase its mobility, namely, the use of the lighting battery for propulsion purposes. A foot-operated push-button is provided, which energises a contactor connecting this battery to the traction motor armature and series field only. Under these conditions the vehicle can be propelled at between 3 and 4 m.p.h. on the level, drawing from 40 to 50 amperes from the battery. Starting with a fully-charged battery, it has been found possible to run a 'bus over a distance of more than a mile on the level. The use of this equipment extends beyond depôt and turning circle manoeuvres, for it enables a bus to circumvent road obstructions or a faulty section of overhead, and thus maintain full continuity of service. It will also be appreciated that this independent source of power is a feature possessed by no other form of transport.

III.—Regeneration.

A point to bear in mind regarding regeneration is the benefit derived by the 'buses themselves. The development of the compound field-controlled motor has resulted in an economical and smooth-running equipment. There is also the important saving in brake wear and the general improvement in braking characteristics. These features alone would be a sufficient justification for the system, but there are further advantages to be gained, even if the net amount of current returned to the power system is small. The power will be absorbed by other vehicles and the current localised in the overhead system between one bus and another, a condition which is equal to a gain in conductivity. An alternative way of looking at the matter is to consider the result of regeneration as a means of maintaining the line voltage. The net consumption of power by a 'bus is decreased and the schedule speeds maintained.

To make full use of these advantages is therefore well worth careful consideration in laying out a distribution system. So far as the power supply plant is concerned, there has been some hesitation in dealing with the reverse power. With the rotary converter the difficulty is the reverse current relay, which is normally set at say, 10 per cent. of the current rating, or at a figure just below the safe D.C. no-load running current. The reason for this is that, should a local fault occur on the A.C. side, a non-limited feed back of D.C. current would cause a run-away, and this is one of the considerations which has led to the tramway practice of feeding separate isolated areas and the avoidance of running sub-stations in parallel.

(This Paper will be Concluded in the next Issue).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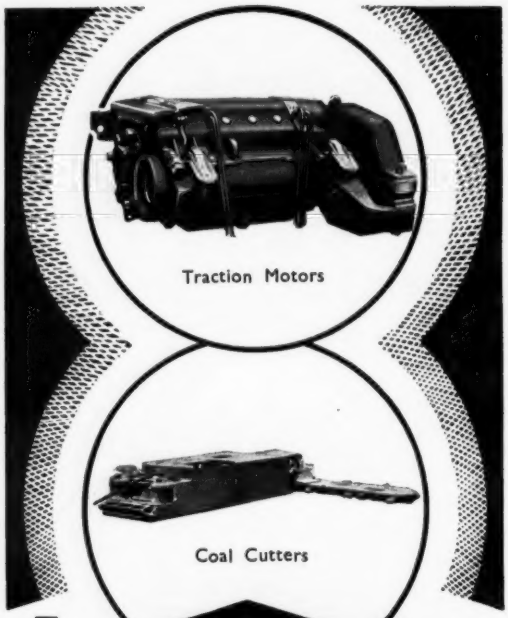

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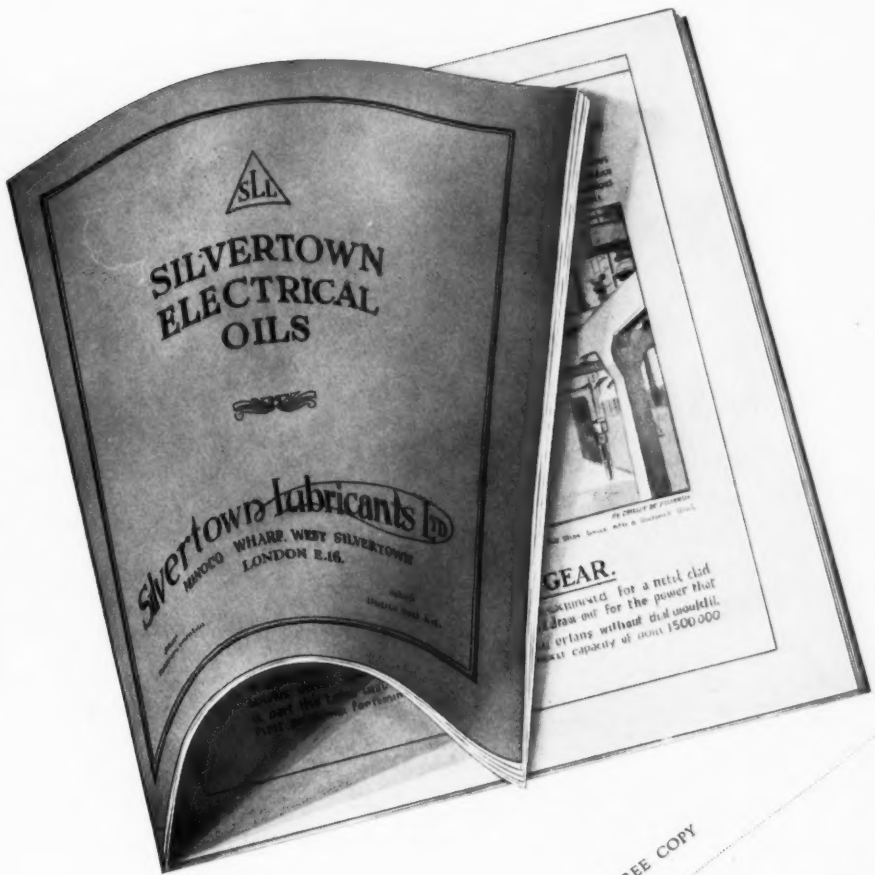

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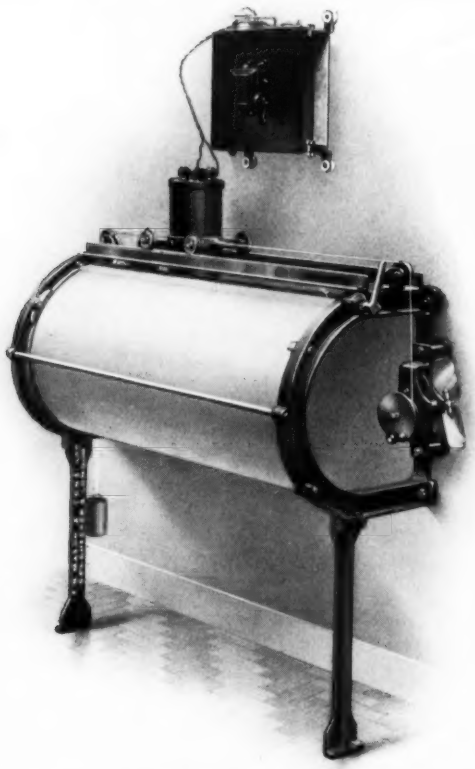

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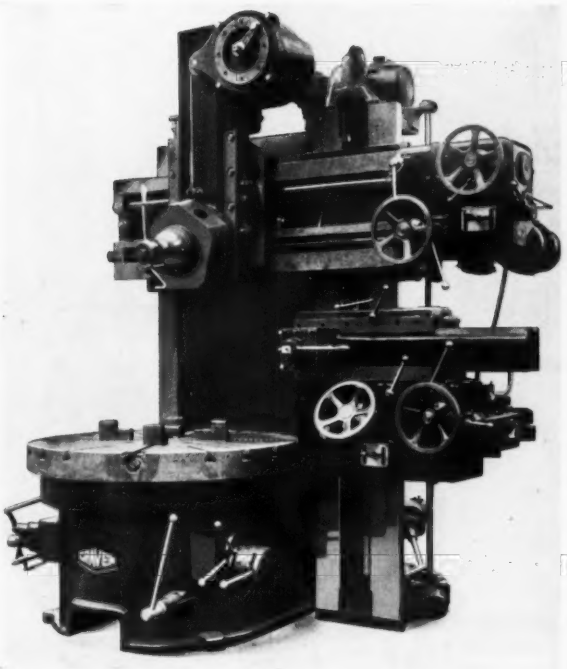

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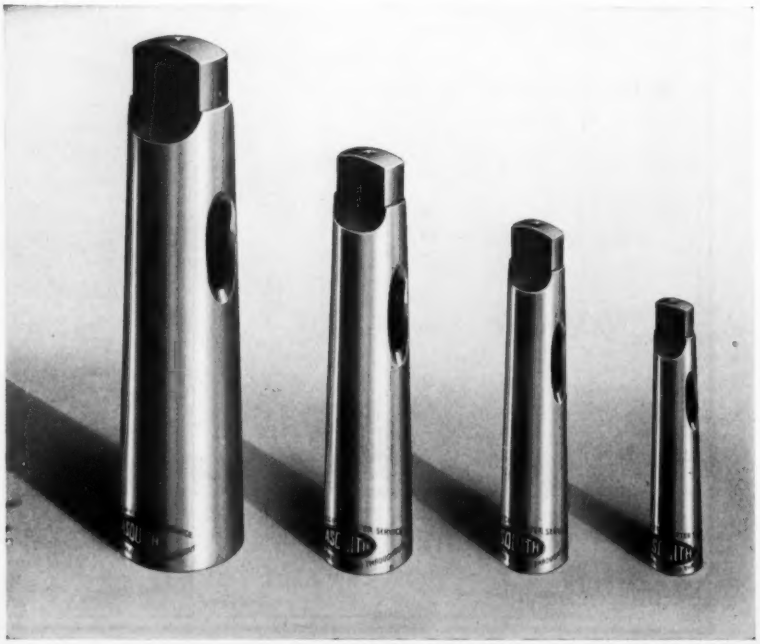

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